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(54) **LIGHTING APPARATUS**

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H05B 33/08 (2006.01)

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CPC ***H05B 37/0272*** (2013.01); ***H05B 33/089*** (2013.01); ***H05B 33/0815*** (2013.01); ***H05B 33/0848*** (2013.01)

(58) **Field of Classification Search**
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USPC ..... 315/291, 297, 307, 209 R
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,100,545	B2 *	1/2012	Dupre et al.	362/20
2013/0175937	A1	7/2013	Nakajo et al.	
2013/0264961	A1 *	10/2013	Chang et al.	315/201
2014/0070699	A1 *	3/2014	Genthon et al.	315/82
2014/0117871	A1 *	5/2014	Swatsky et al.	315/246

FOREIGN PATENT DOCUMENTS

JP	2002-209344	A	7/2002
JP	2007-234415	A	9/2007
JP	2010-182499	A	8/2010
JP	2011-050163	A	3/2011
JP	2013-165630	A	8/2013

* cited by examiner

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(57) **ABSTRACT**

A lighting apparatus includes a light source module and a power supply module. The light source module includes an electrical light source and a transmitter circuit configured to transmit a wireless signal containing information about the light source. The power supply module is connected to the light source module and includes a power supply circuit configured to generate electric power for the light source, a receiver circuit configured to receive the wireless signal transmitted from the transmitter circuit, and a control circuit configured to control the power supply circuit in accordance with the wireless signal received through the receiver circuit.

5 Claims, 2 Drawing Sheets

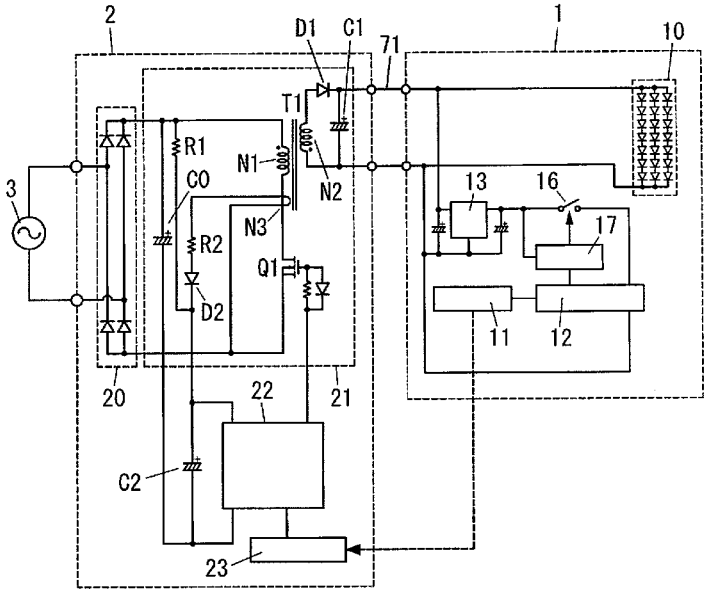
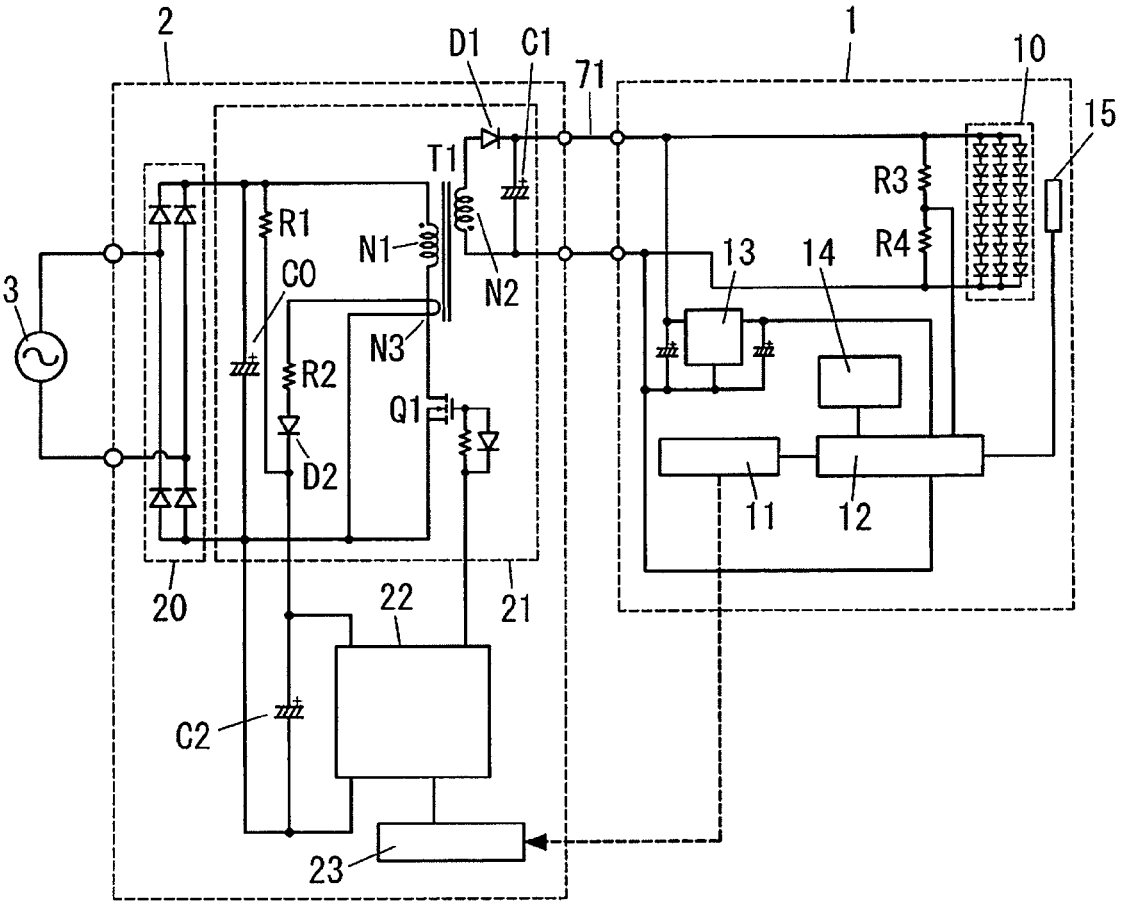


FIG. 1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C0
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R2
Q1
D2
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20
22
21
C2
23

FIG. 2

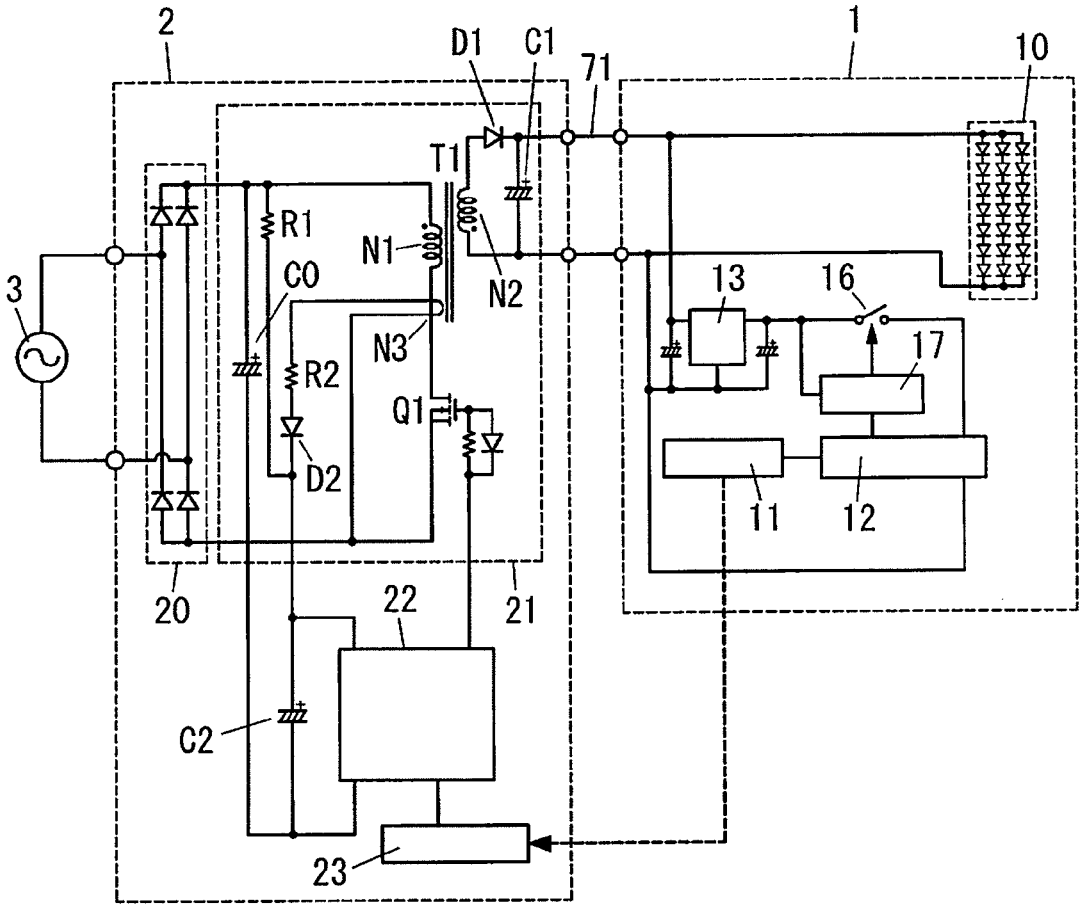
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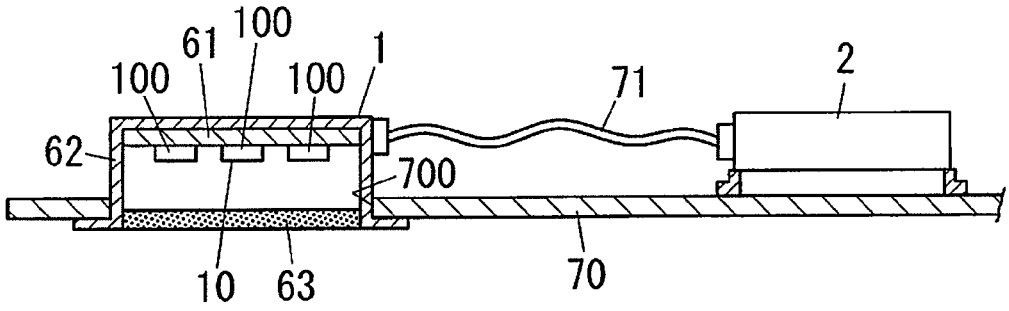
FIG. 3


61
100
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62
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LIGHTING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

The application is based upon and claims the benefit of priority of Japanese Patent Application No. 2013-246659, filed on Nov. 28, 2013, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The invention relates to a lighting apparatus (luminaire).

BACKGROUND ART

Conventionally, there is proposed a lighting apparatus including a light source module having a light source, and a power supply module that is connected to the light source module through wires and configured to generate electric power in order to power the light source (e.g., JP. Pub. No. 2007-234415).

It can be assumed that such a lighting apparatus is provided with a light source module configured to output a signal containing information about a light source thereof (a signal representing presence or absence of a malfunction, a rated current or the like), and a power supply module configured to receive the signal to operate in accordance with the information.

There is however a problem that wiring may be complicated if a signal line for transmitting the signal is provided between the light source module and the power supply module in addition to a power supply line for supplying electric power from the power supply module to the light source module.

SUMMARY

The present invention has been achieved in view of the above circumstances, and an object thereof is to provide a lighting apparatus capable of simplifying wiring.

In an aspect of the invention, a lighting apparatus includes a light source module and a power supply module. The light source module includes an electrical light source and a transmitter circuit. The transmitter circuit is configured to transmit a wireless signal containing information about the light source. The power supply module is connected to the light source module and includes a power supply circuit, a receiver circuit and a control circuit. The power supply circuit is configured to generate electric power for the light source. The receiver circuit is configured to receive the wireless signal transmitted from the transmitter circuit. The control circuit is configured to control the power supply circuit in accordance with the wireless signal received through the receiver circuit.

In the lighting apparatus, the wiring can be simplified in comparison with a case where the information about the light source is transmitted through wires.

BRIEF DESCRIPTION OF THE DRAWINGS

The figures depict one or more implementations in accordance with the present teaching, by way of example only, not bay way of limitations. In the figure, like reference numerals refer to the same or similar elements where:

FIG. **1** is a circuit diagram of an embodiment of the present invention;

FIG. **2** is a circuit diagram showing a modified example of the embodiment; and

FIG. **3** shows a schematic configuration of the embodiment.

DETAILED DESCRIPTION

As shown in FIG. **1**, a lighting apparatus in accordance with an aspect of the present invention includes a light source module **1** and a power supply module **2** electrically connected to the light source module **1**. The light source module **1** includes an electrical light source **10** and a transmitter circuit **11** configured to transmit a wireless signal containing information about the light source **10**. The power supply module **2** includes a power supply circuit **21** configured to generate electric power for the light source **10**, a receiver circuit **23** configured to receive the wireless signal transmitted from the transmitter circuit **11**, and a control circuit **22** configured to control the power supply circuit **21** in accordance with the wireless signal received through the receiver circuit **23**.

In the lighting apparatus, the wireless signal may be a signal representing a characteristic of the light source **10**.

In the lighting apparatus, the wireless signal may be a signal representing at least one of a malfunction of the light source **10**, a temperature of the light source **10**, and a cumulative lighting time of the light source **10**.

In the lighting apparatus, as shown in FIG. **2**, the light source module **1** may include a switch **16** configured to stop power supply to the transmitter circuit **11** after the wireless signal is transmitted.

In the lighting apparatus, the light source module **1** of the lighting apparatus is one of different light source modules of which rated outputs are different from each other. The transmitter circuit **11** is configured to transmit a wireless signal representing a rated output of the light source module **1** of the lighting apparatus. The control circuit **22** is configured to control the power supply circuit **21** so that it outputs electric power corresponding to a rated output of a minimum light source module of the different light source modules until the receiver circuit **23** receives the wireless signal. The minimum light source module is a light source module, having a minimum rated output, of the different light source modules. The control circuit **22** is configured to control the power supply circuit **21** so that it outputs electric power corresponding to the rated output represented by the wireless signal after the receiver circuit **23** receives the wireless signal. In another example, the control circuit **22** is configured to control the power supply circuit **21** so that it outputs electric power corresponding to a value in a range of which maximum value is set to the rated output represented by the wireless signal after the receiver circuit **23** receives the wireless signal. In this example, a minimum value of the range may be previously set.

Hereinafter, a best mode of the embodiment is explained with reference to figures.

As shown in FIG. **1**, a lighting apparatus of the embodiment is provided with a light source module **1** including an electrical light source **10** and a power supply module **2** electrically connected to the light source module **1** through a power line **71** (two wires in the figure). Examples of the light source **10** include a light-emitting diode, a light-emitting diode array and a light source such as an organic electroluminescence device.

The power supply module **2** includes a diode bridge **20**, a power supply circuit **21** and a control circuit **22**. The diode bridge **20** is configured to full-wave rectify AC (alternating current) power from an external AC power supply **3**. The

power supply circuit **21** is configured to convert DC (direct current) input from the diode bridge **20** into prescribed DC output. For example, the DC input (signal) is converted into the DC output (signal) having a prescribed voltage or current. The control circuit **22** is configured to control the power supply circuit **21**. A negative output terminal of the diode bridge **20** is electrically connected to ground.

For example, the power supply circuit **21** is formed of a flyback converter. The flyback converter includes a transformer T**1**, a switching device Q**1**, a diode D**1** and a capacitor C**1** (an output capacitor). The transformer T**1** includes primary and secondary windings N**1** and N**2**. A first end of the primary winding N**1** is connected to a positive output terminal of the diode bridge **20**. The switching device Q**1** is connected between a second end of the primary winding N**1** and a negative output terminal of the diode bridge **20**. The power supply circuit **21** is further provided with a capacitor C**0**. The capacitor C**0** is as across-the-line capacitor for noise reduction which is connected between the output terminals of the diode bridge **20** and connected in parallel with a series circuit of the primary winding N**1** and the switching device Q**1**. A series circuit of the diode D**1** and the capacitor C**1** is connected between both ends of the secondary winding N**2** of the transformer T**1**. The diode D**1** is provided so as to allow an electric current to flow from the transformer T**1** (the secondary winding N**2**) to a side of the capacitor C**1** when power supply to the primary winding N**1** is stopped (the switching device Q**1** is turned off). A voltage across the capacitor C**1** is an output voltage of the power supply circuit **21**. That is, when the switching device Q**1** is turned on, energy is stored in the transformer T**1**. When the switching device Q**1** is turned off, the energy stored in the transformer T**1** is released and supplied to a secondary side. As a result, the capacitor C**1** is charged through the diode D**1**.

Operational examples of the control circuit **22** include a constant current control for adjusting an output current of the power supply circuit **21** to a prescribed target current and a constant voltage control for adjusting an output voltage of the power supply circuit **21** to a prescribed target voltage. For example, in a case of the constant current control, the control circuit **22** is configured to drive (turn on and off) the switching device Q**1** while changing on-duty thereof at all times so that the output current of the power supply circuit **21** is kept at a level of the target current. This configuration of the control circuit **22** can be realized by a microcomputer (a processor) and accordingly detailed explanation and drawings are omitted. In a case of the constant voltage control, when the light source **10** includes a light-emitting diode(s), it is desirable that a resistor for current limiting (not shown) be connected in series to the light source **10**.

The power supply module **2** is further provided with a series circuit of a resistor (a first resistor) R**1** and a capacitor C**2**, which is connected between the output terminals of the diode bridge **20**. The capacitor is a capacitor for control power supply that is a power supply for the control circuit **22**. The transformer T**1** is also provided with a tertiary winding N**3**. A first end of the tertiary winding N**3** is electrically connected to ground, and a second end of the tertiary winding N**3** is electrically connected to a junction of the resistor R**1** and the capacitor C**2** through a series circuit of a resistor (a second resistor) R**2** and a diode D**2**. A cathode of the diode D**2** is electrically connected to the junction of the resistor R**1** and the capacitor C**2**, and an anode of the diode D**2** is electrically connected to the resistor R**2**. That is, the capacitor C**2** is to be charged by an output voltage of the diode bridge **20** and a voltage induced across the tertiary winding N**3**.

The light source module **1** includes a transmitter circuit **11** configured to transmit a wireless signal containing information about the light source **10**, and a transmitter control circuit **12** configured to control the transmitter circuit **11**. The power supply module **2** includes a receiver circuit **23** configured to receive the wireless signal transmitted from the transmitter circuit **11**. The control circuit **22** is configured to control the power supply circuit **21** in accordance with the wireless signal received through the receiver circuit **23**. Examples of the wireless signal include a radio signal and a light signal. In any case, the transmitter circuit **11** and the receiver circuit **23** can be realized by various techniques, and accordingly detailed explanation and drawings are omitted. The transmitter control circuit **12** can be realized by, e.g., a microcomputer (a processor) and accordingly detailed explanation and drawings are omitted.

The light source module **1** further includes a power supply circuit **13** as a transmitter power supply configured to generate a power supply for the transmitter circuit **11** and the transmitter control circuit **12** by appropriately stepping down a voltage from the power supply module **2**. For example, the power supply circuit **13** can be formed of a three-terminal regulator. In an example, the light source module **1** of the lighting apparatus is one of different light source modules of which rated outputs are different from each other.

In a desirable embodiment, the transmitter control circuit **12** is configured to previously store information (request power information) about electric power (a rated output) for a rated lighting of the light source **10**. Examples of the request power information include information about a rated voltage of the light source **10** and information about a rated current of the light source **10**. The transmitter control circuit **12** is configured to control the transmitter circuit **11** so that it transmits a wireless signal (a request power signal) containing the request power information as a characteristic of the light source **10**. In the power supply module **2**, the control circuit **22** is configured to control the power supply circuit **21** so that it outputs electric power corresponding to a light source module **1** (a minimum light source module **1**), having a minimum rated voltage or current, of predetermined different light source modules **1** until the receiver circuit **23** receives the request power signal. That is, the power supply circuit **21** is to output electric power corresponding to a minimum rated voltage or current of the minimum light source module **1**. The control circuit **22** is also configured to control the power supply circuit **21** so that it outputs electric power corresponding to the request power information after the receiver circuit **23** receives the request power signal. For example, in a case where the request power information is information about a rated current of the light source **10** connected to the power supply module **2**, the control circuit **22** may be configured to set the target current to the rated current of the minimum light source module **1** until the request power signal is received, and then to set a maximum value of the target current to a rated current represented by the request power signal after it is received.

In a desirable embodiment, the light source module **1** includes a clocking circuit **14** configured to measure a cumulative lighting time of the light source **10**. The transmitter control circuit **12** is configured to control the transmitter circuit **11** so that it periodically transmits a wireless signal representing the cumulative lighting time measured through the clocking circuit **14**. In the power supply module **2**, the control circuit **22** is configured to allow the power supply circuit **21** to increase the output power thereof according to an increase in the cumulative lighting time so that an optical output of the light source **10** is kept constant by compensating

a reduction in luminous flux in response to the increase in the cumulative lighting time. For example, the optical output (luminous flux at a glance) is kept at 70% of an optical output at a rated lighting of a new light source **10**. The optical output may be varied by changing on-duty for intermittent lighting or varied by increasing or decreasing an output current (a target current) of the power supply circuit **21**.

In a desirable embodiment, the light source module **1** includes a temperature detector **15** which is placed in proximity to the light source **10** and configured to detect (measure) a temperature of the light source **10**. For example, the temperature detector **15** may be formed of a thermistor. The transmitter control circuit **12** is configured to control the transmitter circuit **11** so that it periodically transmits a wireless signal representing the temperature detected through the temperature detector **15**. In the power supply module **2**, the control circuit **22** is configured to decrease an output power of the power supply circuit **21** or deactivate the power supply circuit **21** in a case where the temperature represented by the wireless signal received through the receiver circuit **23** is higher than a prescribed temperature. In general, a forward voltage of a light-emitting diode more decreases as a temperature thereof becomes lower. The control circuit **22** may be therefore configured to more increase an output voltage (a target voltage) of the power supply circuit **21** as the temperature detected through the temperature detector **15** becomes lower in a case where the electrical light source **10** is formed of one or more light-emitting diodes and the control circuit **22** is configured to control the power supply circuit **21** in accordance with the constant voltage control.

In a desirable embodiment, the transmitter control circuit **12** is configured to determine whether or not a malfunction in the light source **10** occurs, based on a voltage across the light source **10** in a case where the control circuit **22** is configured to control the power supply circuit **21** in accordance with the constant current control. Examples of the malfunction include a short circuit and an open-circuit (no-load). The voltage across the light source **10** is detected with a voltage divider connected in parallel with the light source **10**. In FIG. **1**, the voltage divider is formed of a series circuit of resistors R**3** and R**4**. The transmitter control circuit **12** is configured to determine that the open-circuit occurs if the voltage across the light source **10** is higher than a first threshold, and to then control the transmitter circuit **11** so that it transmits a wireless signal representing occurrence of the open-circuit. The transmitter control circuit **12** is also configured to determine that the short-circuit occurs if the voltage across the light source **10** is lower than a second threshold that is lower than the first threshold, and to then control the transmitter circuit **11** so that it transmits a wireless signal representing occurrence of the short-circuit. In the power supply module **2**, the control circuit **22** is configured to decrease the output (an output voltage or current) of the power supply circuit **21** or deactivate the power supply circuit **21** when the receiver circuit **23** receives a wireless signal representing an open-circuit or a short-circuit.

In the aforementioned configurations, the wiring between the power supply module **2** and the light source module **1** can be simplified in comparison with a case where the information about the light source **10** is transmitted through wires.

In a desirable embodiment, the lighting apparatus is configured to stop power supply to the transmitter circuit **11** after a wireless signal is transmitted in a case where the wireless signal representing, e.g., a characteristic of the light source **10** is transmitted only just after the lighting apparatus is started (the power supply module **2** starts supplying electric power). In a concrete example of FIG. **2**, the light source module **1** is provided with a switch **16** intervened between the power supply circuit **13** and both of the transmitter circuit **11** and the transmitter control circuit **12**, and a switch driver circuit **17** configured to drive (turn on or off) the switch **16**. The switch driver circuit **17** is configured to turn on the switch **16** in a first time period and to turn off the switch **16** in a second time period. The first time period is a time period until the transmission of the wireless signal is completed after the lighting apparatus is started. The second time period is a time period(s) other than the first time period, e.g., a time period until the lighting apparatus is deactivated after the transmission of the wireless signal is completed. For example, the switch **16** may be formed of a semiconductor switch. If the power supply to the transmitter circuit **11** and the transmitter control circuit **12** is stopped, power consumption can be suppressed in comparison with a case where electric power is always supplied to the transmitter circuit **11** and the transmitter control circuit **12**.

Examples of the above-mentioned characteristic of the light source **10** represented by the wireless signal include a forward voltage of the light source **10**, the number of light-emitting diodes constituting the light source **10**, a color temperature of light from the light source **10**, and the like.

Preferably, the light source module **1** is provided with an instruction input device (not shown) configured to receive an instruction for changing the characteristic of the light source **10** represented by the wireless signal. The transmitter control circuit **12** may be configured to change information to be contained in a wireless signal in accordance with the instruction received through the instruction input device.

In an embodiment, the power supply circuit **21** may be formed of a switching regulator such as a buck converter, and a combination circuit of a boost converter and a buck converter connected to a latter part of the boost converter.

FIG. **3** illustrates a schematic configuration of the lighting apparatus. In an example of FIG. **3**, a light source module **1** includes a printed wiring board **61** and light-emitting diodes **100** constituting a light source **10** mounted on a mount surface of the printed wiring board **61**. The light source module **1** further includes a case **62** and a light-transmitting cover **63**. The case **62** is shaped like a tube having a top base and a bottom opening. The printed wiring board **61** is fixed to an inner face of the top base with the mount surface side down. For example, the cover **63** is formed of material such as acrylic resin so as to have optically transparency. The cover **63** closes the bottom opening of the case **62**. The case **62** is recessed in a through hole **700** cut in a ceiling member **70**, and light of the light source **10** is to be emitted downward through the light-transmitting cover **63**. The ceiling member **70** is a board member that is fixed with a space (a wiring space) provided between the board member and building parts such as concrete so that a thickness direction of the board member is parallel with a vertical direction. Bottom surfaces of the ceiling members **70** constitute a ceiling plane. The power supply module **2** is placed on a top surface of the ceiling member **70** beside the light source module **1** and electrically connected to the light source module **1** through a cable (the power line) **71**. The necessary space above the ceiling members **70** can be reduced in comparison with a case where the power supply module **2** is placed on an upper side of the light source module **1**. By providing a connector at an end or each end of the cable **71**, the light source module **1** and the power supply module **2** can be easily connected to or disconnected from each other.

While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the sub-

ject matter disclosed herein may be implemented in various forms and examples, and that they may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all modifications and variations that fall within the true scope of the present teachings.

The invention claimed is:

1. A lighting apparatus, comprising:

a light source module comprising an electrical light source and a transmitter circuit configured to transmit a wireless signal containing information about the light source; and

a power supply module that is connected to the light source module and comprises a power supply circuit configured to generate electric power for the light source, a receiver circuit configured to receive the wireless signal transmitted from the transmitter circuit, and a control circuit configured to control the power supply circuit in accordance with the wireless signal received through the receiver circuit,

wherein the wireless signal represents a characteristic of the light source, and

the light source module comprises a switch configured to stop power supply to the transmitter circuit after the wireless signal is transmitted.

2. The lighting apparatus of claim **1**, wherein the wireless signal represents at least one of a malfunction of the light source, a temperature of the light source, and a cumulative lighting time of the light source.

3. A lighting apparatus, comprising:

a light source module comprising an electrical light source and a transmitter circuit configured to transmit a wireless signal containing information about the light source; and

a power supply module that is connected to the light source module and comprises a power supply circuit configured to generate electric power for the light source, a receiver circuit configured to receive the wireless signal transmitted from the transmitter circuit, and a control circuit configured to control the power supply circuit in accordance with the wireless signal received through the receiver circuit,

wherein

the light source module of the lighting apparatus is one of different light source modules of which rated outputs are different from each other,

the transmitter circuit is configured to transmit a wireless signal representing a rated output of the light source module of the lighting apparatus,

the control circuit is configured to control the power supply circuit so that the power supply circuit outputs electric power corresponding to a rated output of a minimum light source module of the different light source modules until the receiver circuit receives the wireless signal, the minimum light source module being a light source module, having a minimum rated output, of the different light source modules, and

the control circuit is configured to control the power supply circuit so that after the receiver circuit receives the wireless signal, the power supply circuit outputs electric power:

corresponding to the rated output represented by the wireless signal; or

corresponding to a value in a range of which maximum value is set to the rated output represented by the wireless signal.

4. The lighting apparatus of claim **3**, wherein the wireless signal represents a characteristic of the light source.

5. The lighting apparatus of claim **3**, wherein the wireless signal represents at least one of a malfunction of the light source, a temperature of the light source, and a cumulative lighting time of the light source.

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